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180/65.21-65.29; 701/1, 67, 69, 101
See application file for complete search history.

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- (57) **ABSTRACT**

- In a vehicle provided with a power propulsion system of the mild-hybrid type, a BAS unit—including an electric machine connected through a belt transmission to the shaft of an internal combustion engine—is exploited as the only propulsion engine of the vehicle in given operating conditions. The internal combustion engine is provided with a system for variable actuation of the intake valves which is controlled to reduce the pumping losses of the internal combustion engine in the phase in which such engine is in cut-off condition and it is driven by the aforementioned BAS unit. It is also provided for that the system for variable actuation of the intake valves be controlled to temporarily increase the pumping losses of the internal combustion engine in a phase in which it is required to accelerate the switching off of the engine.

- 14 Claims, 5 Drawing Sheets**

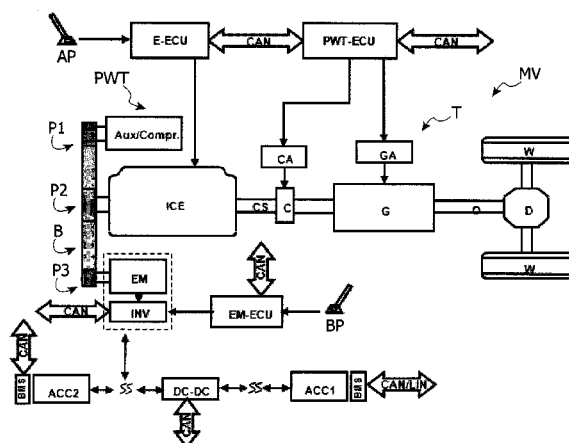
- 14 Claims, 5 Drawing Sheets**

- 14 Claims, 5 Drawing Sheets**

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F01L 9/02 (2006.01)
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F01L 1/26 (2006.01)
- (52) **U.S. Cl.**
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(2013.01); **B60W 30/18072** (2013.01); **F01L**
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(2013.01); **F02D 41/042** (2013.01); **F02D**
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B60W 2510/101 (2013.01); **B60W 2510/1005**
(2013.01); **B60W 2520/10** (2013.01); **B60W**
2540/10 (2013.01); **B60W 2540/12** (2013.01);
B60W 2710/0633 (2013.01); **B60Y 2300/525**
(2013.01); **F01L 1/185** (2013.01); **F01L 1/267**
(2013.01); **F01L 2105/00** (2013.01); **F01L**
2820/01 (2013.01); **F02D 2041/001** (2013.01);
Y02T 10/18 (2013.01); **Y02T 10/42** (2013.01);
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FIG. 1

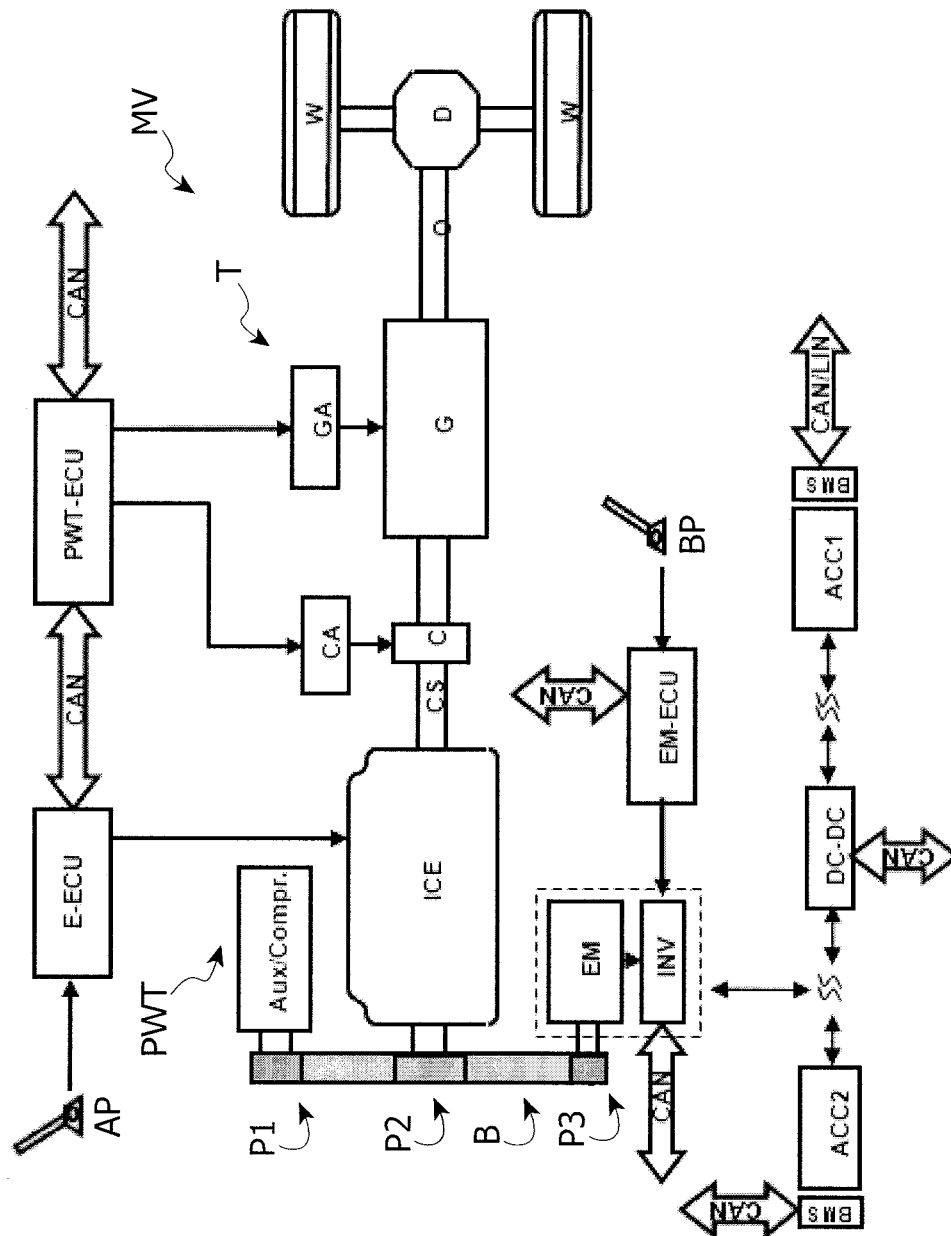


FIG. 2

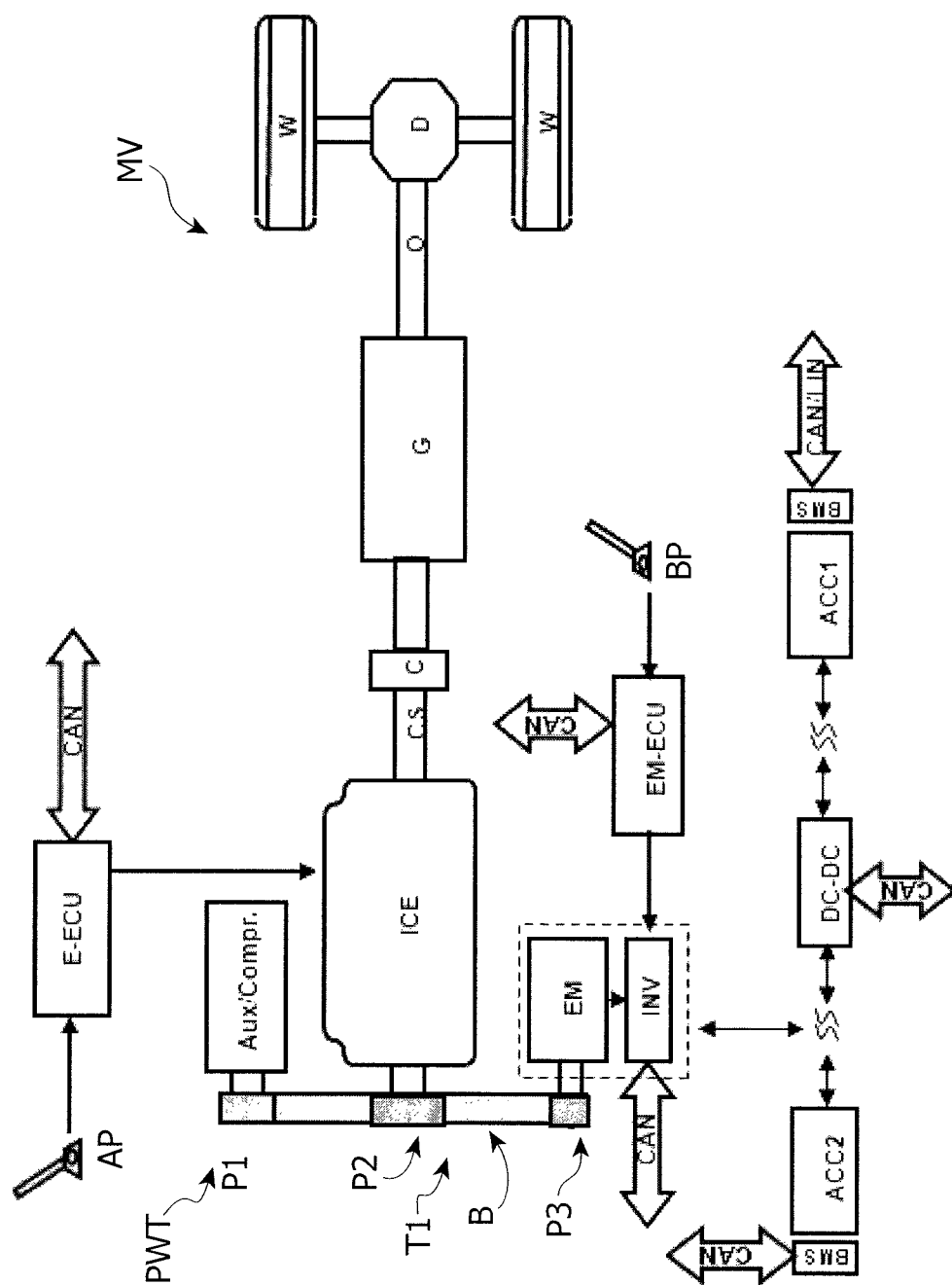


FIG. 3

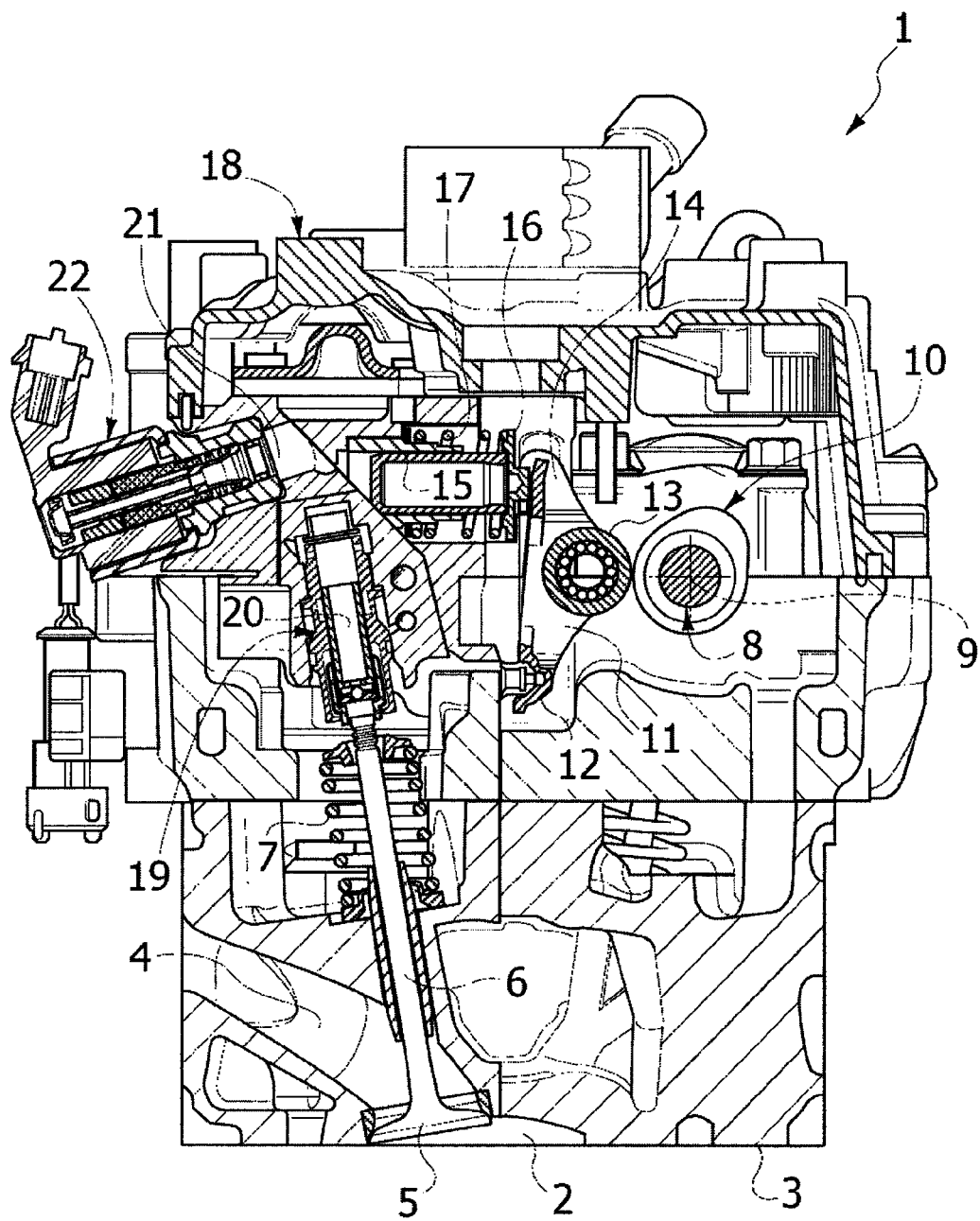


FIG. 4

(Prior Art)

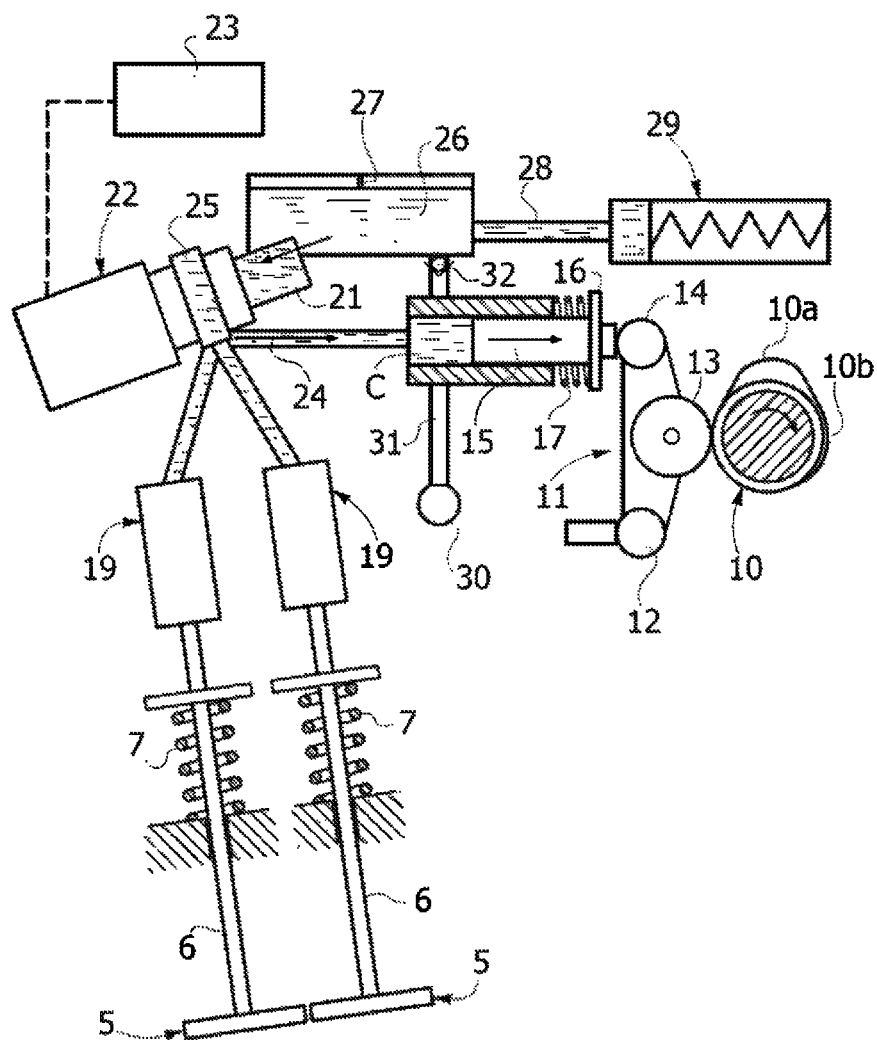


FIG. 5

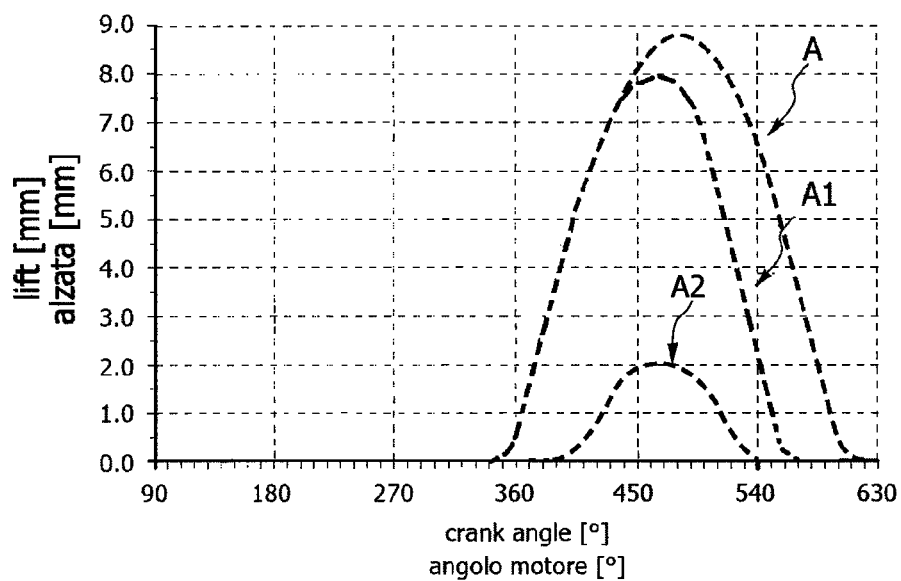
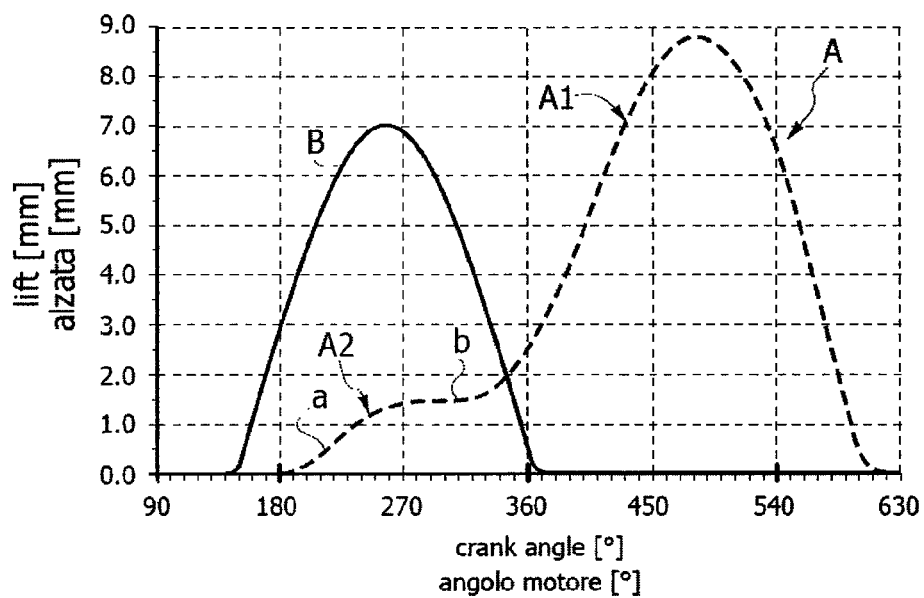


FIG. 6



**METHOD FOR CONTROLLING A
MOTOR-VEHICLE PROVIDED WITH A
PROPULSION SYSTEM OF THE
“MILD-HYBRID” TYPE**

**CROSS REFERENCE TO RELATED
APPLICATIONS**

This application is a 371 National Phase of PCT International Application No. PCT/IB2012/053428 filed on Jul. 5, 2012, and published in English as WO 2013/050886 A1 on Apr. 11, 2013, which claims priority to European Patent Application No. 11183660.7 filed on Oct. 3, 2011, the entire disclosures of which are incorporated herein by reference.

The present invention regards a method for controlling a motor vehicle of the type comprising:

- an internal combustion engine, having a drive shaft with an output end, connected through a transmission to at least one pair of wheels of the motor vehicle, and an upstream end connected through a belt transmission to one or more auxiliary devices, such as for example the air conditioning system compressor,
- a BAS (Belt Alternator Starter) unit constituted by an electric machine connected to said upstream end of the drive shaft through said belt transmission and controlled to operate both as an electrical power generator, as an electric motor for starting the internal combustion engine, and as an auxiliary engine for the propulsion of the motor vehicle, additionally to the internal combustion engine.

Motor vehicle power propulsion systems of the type indicated above have been known and used over the years. Examples of a motor vehicle power propulsion systems of this type are for example described in documents DE-A-30 09 503, FR-A-2 32 358. A solution of the type indicated above is in particular described and illustrated in the document US 2008/0249695 A1. The power propulsion systems of this type are also referred to as mild-hybrid systems.

The object of the present invention is to provide a system of the type indicated above capable of allowing new and more efficient operating modes with respect to the systems provided up to date and having a relatively simple and economical structure.

With the aim of attaining such object, the invention aims at providing a method for controlling a motor vehicle having all the characteristics indicated at the beginning of the present description and further characterised in that;

- in given engine operating conditions said BAS unit is used as the only propulsion engine of the motor vehicle, maintaining the internal combustion engine in a cut-off condition and using the drive shaft as a simple transmission shaft,
- said internal combustion engine is provided with a system for variable actuation of the intake valves, and
- in the aforementioned operating conditions in which the BAS unit is used as the only propulsion engine, the system for variable actuation of the intake valves of the internal combustion engine is controlled to vary the opening time and/or closing time and/or lift of the intake valves so as to reduce the losses due to the pumping effect which occur within the internal combustion engine when it is driven in rotation by said BAS unit in cut-off condition.

Preferably, in the aforementioned operating conditions in which the BAS unit is used as the only propulsion engine the system for variable actuation of the intake valves of the inter-

nal combustion engine is controlled to close the intake valves in advance with respect to a conventional intake cycle.

Though the system for variable actuation of the intake valves can theoretically be of any known type, it is preferred, according to the invention, that it be provided with a system of the known type sold under the trademark MULTIAIR and developed by the applicant. Such system is described in various patents and patent applications of the applicant, including for example document EP-A-1 936 132 and the European patent application EP 10425210.1 (still not open to public inspection as of date of priority of the present application).

According to the aforementioned solution developed by the applicant, the system for variable actuation of the engine valves comprises at least one camshaft connected to the drive shaft, each intake valve being controlled by a respective tappet actuated by a respective cam of said camshaft, against the action of spring means associated to each intake valve which return the valve towards a closed position. The tappet is connected to the intake valve through hydraulic actuation means comprising a pressure hydraulic chamber, which can be connected to an exhaust channel through an electronically controlled solenoid valve, so as to decouple the intake valve from the respective cam and cause the closure thereof due to said spring means.

As indicated above, the method according to the invention also provides for, among the various operating modes, an operating mode of the so-called e-monitoring type, i.e. in which the vehicle is solely operated by one electric engine, without any contribution of the internal combustion engine. In such phase, the internal combustion engine is off and the shaft thereof serves as a transmission shaft between the BAS unit, which is connected through the belt transmission to the upstream end of the internal combustion engine shaft, and the transmission of the vehicle downstream of the internal combustion engine, connecting the output end of the drive shaft with the wheels of the vehicle. In the known art of the mild-hybrid systems, such operating mode is generally avoided, in that it is deemed that the driving of the internal combustion engine shaft, with ensuing passive actuation of the pistons thereof, leads to a pumping effect which determines excessive losses and low performance. However the application of such solution to an internal combustion engine provided with a system for variable actuation of the intake valves, preferably of the MULTIAIR system described above, allows reducing the aforementioned pumping losses to a level sufficient to guarantee an operation with suitable performance.

As indicated above, the reduction of the pumping losses is obtained for example through a closure of the intake valves in advance obtained through activation of the solenoid valves part of the aforementioned MULTIAIR system, which connect the pressure chamber to discharge and consequently cause a quick closure of the intake valves in advance with respect to the lift profile of the respective actuation cam.

Alternatively or additionally to the solution described above, with the aim further reducing the pumping losses of the internal combustion engine, when it is in the cut-off condition and it is driven by the BAS unit, the aforementioned system for variable actuation of the intake valves is preferably provided for opening the intake valves during a phase which—during the normal operation of the engine—corresponds to the exhaust phase, so as to obtain a recirculation—in each cylinder—of the exhaust gases produced in the engine immediately before the cut-off phase. In such operating mode, there can be provided a control of the intake valve thus a mass of burnt gases continuously moves between the supply conduit and the combustion chamber of each cylinder, so as to

avoid the entry of comburent and fuel in the cylinders, with ensuing reduction of the pumping losses.

According to a further embodiment, the system for variable actuation of the intake valves is controlled so as to differently actuate the intake valves associated to different cylinders of the internal combustion engine and so as to differently control the intake valve over time, as a function of the engine cylinders operating conditions detected by the electronic control unit through a plurality of sensors.

Further characteristics and advantages of the invention will be apparent from the following description with reference to the attached drawings, provided purely by way of non-limiting example, wherein:

FIG. 1 illustrates a block diagram of a power propulsion system of a motor vehicle of the "mild-hybrid" type, according to a preferred embodiment of the present invention,

FIG. 2 illustrates a simplified variant of the system of the FIG. 1,

FIGS. 3, 4 are a sectional view and a corresponding schematic view of an internal combustion engine according to the aforementioned known art, previously developed by the applicant (see for example EP-A-1 936 132), and

FIGS. 5, 6 are diagrams showing the lift profiles of the intake valves of the internal combustion engine in two different embodiments of the invention.

With reference to FIG. 1, a motor vehicle MV comprises a power transmission unit including a power propulsion system PWT and a transmission system T. The power propulsion system PWT includes an internal combustion engine ICE and a reversible electric machine EM. The power propulsion system may also comprise one or more auxiliary devices AUX, for example including an air conditioning system compressor. The electric engine EM and the auxiliary components AUX are connected to the internal combustion engine ICE through a belt transmission B including a belt and a plurality of pulleys P1, P2, P3 and a belt-stretching device (not illustrated, which can be of any known type). The pulley P3 is mounted on the output shaft of the electric machine EM, which constitutes a BAS unit adapted to operate as an alternator, for generating electrical power, when it is driven by the internal combustion engine, as a starter for starting the internal combustion engine, and as an electric motor for actuating auxiliary devices AUX. Furthermore, as indicated hereinafter, the machine EM can also be used, in given operating conditions, as the only propulsion engine of the vehicle. The pulley P2 is mounted on the upstream end of the internal combustion engine shaft ICE, while one or more pulleys P1 (only one of which is illustrated) is mounted on the shaft of each auxiliary device, if required by interposing an engagement device, which allows decoupling the auxiliary device from the belt transmission. As indicated, the system of pulleys P1, P2, P3 and the transmission belt B are capable of transmitting the propulsion torque produced by the electric machine to the shaft of the engine ICE and to the auxiliary components AUX and vice versa transmitting the propulsion torque produced by the engine ICE to the electric machine EM and to the auxiliary components AUX through the internal combustion engine. The power propulsion system PWT includes two electrical sections V1, V2 with different voltages to which there are respectively connected two accumulators ACC1, ACC2, auxiliary electric loads and a DC-DC voltage converter capable of bidirectionally controlling the energy exchange between the two sections. The power propulsion system further includes an inverter INV for the power control of the electric machine EM.

The transmission line T comprises a gearbox G of the electric, or electrohydraulic, or electromechanical type, with

discrete ratios, of the of the gear type, having an input shaft that can be coupled to the drive shaft CS through an engagement and one or more clutches C and an output shaft or coupled to a pair of drive wheels W through a differential D of any known type. The clutch C, which can be single or double, is servo-controlled through an associated actuator CA with electric or electrohydraulic control. Also the gearbox G is servo-controlled through a plurality of actuators with electric or electrohydraulic or electromechanical control, indicated in its entirety with GA, which can be operated to perform the engagement and the disengagement of the gears corresponding to the different obtainable gear ratios.

The internal combustion engine ICE is controlled by an electronic control unit E-ECU of the per se known type and thus not described in detail, while the inverter INV of the electric machine EM is controlled by an electronic control unit EM-ECU. Therefore the power transmission unit PWT includes three electronic control units (PWT-ECU, E-ECU and EM-ECU) capable of respectively controlling the transmission line alongside the gearbox unit, the internal combustion engine and the electric machine EM. The aforementioned electronic control units exchange messages through a network CAN.

FIG. 2 illustrates, by way of example, a simplified variant in which the gearbox G is of the conventional type, controlled manually.

FIG. 3 and FIG. 4 of the attached drawings refer to an example of an internal combustion engine of the known type provided with the MULTIAIR system developed by the applicant, for the variable actuation of the intake valves. FIG. 1 illustrates in particular a sectional view of a cylinder head of a four-cylinder internal combustion engine.

With reference to FIG. 3, the cylinder head, indicated in its entirety with reference number 1, comprises, for each cylinder, a cavity 2 formed on the lower surface thereof 3 defining the combustion chamber, in which two intake conduits 4 (only one of which is shown in the figure) and two exhaust conduits (not shown in the figure) terminate. The communication of the two intake conduits to the combustion chamber 2 is controlled by two intake valves 5 (only one of which is shown in the figure) each comprising a stem 6 slidably mounted in the body of the head 1. Each valve 6 is returned towards the closure position by a spring 7 interposed between an inner surface of the head 1 and an end cup of the valve. The communication of the two exhaust conduits to the combustion chamber is controlled by two valves of the conventional type (not shown in the figure) to which there is also associated springs for return towards the closed position.

The opening of each intake valve 6 is controlled, as described hereinafter, by a camshaft 8 mounted rotatably around an axis 9 within supports (not shown in the figure) of the head 1, and comprising a plurality of cams 10 for the actuation of the intake valves 5.

Each cam 10 cooperates with a tappet 11 which in the case of the illustrated example is constituted by an arm oscillatably mounted at an end 12 thereof on the structure of the head cylinders and having a central portion thereof which rotatably freely supports a roller 13 cooperating with the cam 10. The opposite end 14 of the oscillating arm 11 controls a pumping piston 15 through a plate 16 connected to the piston 15. The latter is returned by a spring 17 against the arm 11, so as to maintain the arm 11 in cooperation contact with the cam 10. The pumping piston 15 is slidably mounted in a cavity which is obtained in a pre-assembled block 18 which is mounted on the head 1 and which incorporates all the electrical and hydraulic devices part of the system for variable actuation of

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the intake valves the engine is provided with, according to what is described in detail hereinafter.

The pumping piston **15** is capable of transmitting a thrust to the stem **6** of each intake valve **5**, so as to cause the opening of the latter against the action of the spring **9**, through a pressurised fluid (preferably oil coming from the engine lubrication circuit) present in a pressure chamber **C** to which the pumping piston **15** is faced. Following the thrust applied by the pumping piston **15**, the pressurised oil is transferred from the chamber **C** to the chamber of a hydraulic actuator **19** whose piston **20** pushes the valve **5** towards the open position.

All the previously described parts are also shown in FIG. 4, which shows a schematic representation of the system illustrated in FIG. 3.

With reference to both FIGS. 3, 4, the pressurised fluid chamber **C** associated to the intake valves **5** of each cylinder may be placed in communication with an exhaust channel **21** through a solenoid valve **22** controlled by a programmable electronic control unit **23**. The solenoid valve **22**, which can be of any known type, suitable for the function illustrated herein, is controlled by the control unit **23** as a function of signals **S** indicating engine operation parameters, such as the position of the accelerator and the number of engine revolutions.

When the solenoid valve **22** is open, the chamber **C** enters in communication, through a channel **24** and a circumferential chamber **25** (FIG. 2) with the exhaust channel **21**. Hence the pressurised fluid present in the chamber **C** flows in such channel and there is obtained a decoupling of the cam **10** and the tappet **7** with respect to the intake valves **5**, which thus quickly return in the closure position thereof, under the action of the return springs **9**, should they be in the open condition, corresponding to a phase in which the tappet **11** is in contact with the lobe of the cam **10**.

The exhaust channel **21** communicates, according to a solution previously proposed by the applicant, with a tank **26**, vented at the upper part with respect to the atmosphere in **27**. The tank **26** in turn communicates through a conduit **28** with an accumulator of pressurised fluid **29** (schematically illustrated in the FIG. 2).

Lastly, the exhaust tank **26** communicates with a conduit **30** connected to the engine lubrication circuit through a conduit **31** in which there is interposed a check-valve **32** which allows the fluid to flow only in the direction of the tank **26**.

In the illustrated example, the engine exhaust valves are controlled conventionally, through a respective camshaft and a mechanical transmission. However, according to the invention, it can also not be excluded that the exhaust valves be controlled variably, having a system of the type described above for the intake valves.

In the engine operation, should the solenoid valve **22** be maintained closed, the chamber **C** remains full of pressurised fluid and the movements of the cam **10** are transmitted to the intake valves **5** according to a lift profile which corresponds to the cam profile **10**. The control unit **23** is however programmed to connect the chamber **C** to discharge in given engine operating conditions with the aim of causing the closure of the intake valves even when the cam **10** would tend to keep them open. Thus, such solution allows varying the opening time (as the duration of the opening, as time of start and time of end of the opening) and/or lift of the intake valves at will, for example to obtain a delayed opening and/or advance closure or to obtain a plurality of openings and closures within the conventional intake valves opening phase, according to the description subject of the previous patents of the applicant.

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Still with reference to FIG. 3, it should be observed that the actuator **20** is further provided with hydraulic braking means which slow the final closure travel of the intake valve **5** when the latter closes following an opening of the solenoid valve **22**, so as to avoid an excessive impact and an ensuing damaging of the intake valve upon reaching the closed position. The hydraulic braking means are not described herein, in that they can be obtained in any one of the methods known from the previous patent documents of the applicant.

Returning to the systems illustrated in FIGS. 1 and 2, in both embodiments it is provided for that, in given operating conditions, the vehicle be solely operated by the electric machine **EM** ("e-motoring" condition).

In such operating condition, the internal combustion engine **ICE** is off, i.e. moved to a cut-off condition. In such condition, the pistons of the engine **ICE** move due to the rotation of the drive shaft, which serves as a simple transmission shaft between the pulley **P2** which receives the motion from the electric machine **EM** through the belt transmission **B**, and the transmission system **T**, connecting the output end of the drive shaft **CS** to the wheels **W** of the motor vehicle.

In such operating condition, the system according to the invention is capable reducing the pumping losses due to the movement of the pistons in the engine cylinders, due to the fact that the internal combustion engine **ICE** is provided with a system for variable actuation of the intake valves.

As previously indicated, preferably the system for variable actuation that the engine **ICE** is provided with is the MULTIAIR system developed by the applicant, which was described above with reference to the attached FIGS. 3, 4.

According to a first solution, in the "e-monitoring" phases in which the vehicle is solely operated by the electric machine **EM**, the pumping losses of the engine are reduced closing the intake valve in advance, according to the valve lift scheme illustrated in FIG. 5, where the profile **A** is the lift profile of each intake valve determined by the profile of the respective cam, while the profile **A1** shows an example of valve control with closure in advance, obtainable by connecting the respective pressure chamber to discharge in advance with respect to the normal closure determined by the cam profile.

In a particularly preferred variant of the invention, which is described herein with reference to FIG. 6, the system is also capable of further reducing the losses due to the pumping effect during the e-motoring phase, causing a supplementary opening of the intake valves during the phase theoretically corresponding to the conventional exhaust phase. The use of the MULTIAIR system for obtaining an additional opening of the intake valves during the conventional exhaust phase is per se known for example from the previous document EP-A-1 936 132 of the applicant.

In the case of the preferred embodiment of the present invention, the cams for the actuation of the intake valves of the engine each have, as shown in FIG. 4, a profile comprising a main portion **10a** for causing the opening of the intake valve during the conventional intake phase in the respective cylinder of the engine and an additional portion **10b** for causing a partial opening of the intake valves even during the conventional exhaust phase in the respective cylinder.

FIG. 6 of the attached drawings shows a diagram which represents the lift profiles of the intake valve and the exhaust valve of an engine cylinder thus obtained.

In such figure, the profile **A** is that regarding the lift of the intake valve, and the profile **B** is that regarding the exhaust valve. The diagram shows the lift in mm as a function of the crank angle. In the convention assumed in the diagrams of FIGS. 5 and 6, the 180° crank angle corresponds to the condition in which the piston is at the Bottom Dead Centre, at the

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beginning of the exhaust phase in the cylinder. The 360° angle corresponds to the condition in which the piston has reached the Top Dead Centre, at the end of the exhaust phase and at the beginning of the subsequent intake phase, which theoretically terminates at a crank angle equivalent to 540°, where the piston is once again positioned at the Bottom Dead Centre. As observable in FIG. 6, the profile A has a main portion A1 (having the conventional bell-like shape) which causes the opening of the valve during the normal intake phase in the cylinder and an additional portion A2, which causes an additional lift of the intake valve during the exhaust phase. The additional profile A2 substantially extends starting from an angle equivalent to 180° (Bottom Dead Centre), at the beginning of the exhaust phase, with a first ascending section "a" connected with a second section "b" with substantially constant lift, equivalent to a fraction of the maximum lift achieved by the intake valve during the intake phase. The sections A1 and A2 of the lift profile A of the intake valve are determined by the corresponding cam profile 10 (FIG. 4), having the main portion 10a corresponding to the portion A1 of the lift profile and the additional portion 10b corresponding to the portion A2 of the lift profile.

With the cams profiled as illustrated in FIG. 4, should one intend to cause the supplementary opening of the intake valve during the theoretical exhaust phase, it is sufficient that the control maintains the pressure chamber associated to each intake valve at the profile 10b of the cam. The opening of the intake valves during the theoretical exhaust phase allows sending in the intake conduit of each cylinder part of the exhaust gases previously formed in the last engine operating cycle, immediately before the cut-off required to obtain the e-motoring condition. Suitably controlling the opening and the closure of the intake valves, and maintaining the closed exhaust valves, thus allows such amount of exhaust gas to move alternately between the combustion chamber of each cylinder and the respective intake conduit. This allows avoiding introducing comburent and fuel into each cylinder, hence the pumping losses are minimised.

Obviously it is preferable to adopt both solutions described above, i.e. both the additional opening of the intake valves in the exhaust phase (FIG. 6), and the closure of the intake valves in advance during the conventional intake phase (FIG. 5)

According to a further solution, the invention provides for that said system for variable actuation of the intake valves be controlled so as to differently actuate intake valves associated to different cylinders or so as to differently actuate the same intake valve over time, as a function of the engine operating conditions, which are detected by the electronic control unit through a plurality of sensors.

The e-motoring condition is activated, according to the invention, in a condition in which the motor vehicle is stationary, to execute an "e-launch" strategy, i.e. a vehicle start in stationary condition using the electric propulsion alone and with the internal combustion engine off and driven by the BAS unit.

Entry into the e-motoring condition with the vehicle moving is actuated in case of specific conditions of the vehicle (for example covering road sections with constant power delivered to the ground), the internal combustion engine (for example operation in low efficiency conditions), the electrical system (for example accumulators ACC1 and ACC2 with suitable charge conditions).

Still according to the invention, when the aforementioned e-motoring operating condition is activated, the switching off of the engine is accelerated, with the aim of being able to promptly restart it in case of a change-of-mind of the driver.

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According to a further characteristic of the invention, the acceleration of the switching off is obtained by temporarily increasing (instead of reducing) the pumping losses of the internal combustion engine, by controlling the system for variable actuation of the intake valves such to cause a delayed opening (see line A2 in FIG. 5), or a total absence of opening of the intake valves.

According to the invention, the control logic of the intake valves of the internal combustion engine may be allocated in any of the aforementioned electronic control units. It is automatically activated on the basis of any input, preferably selected from among the following:

- accelerator pedal position signal;
- brake pedal position signal;
- clutch condition signal (both for manual and robotized gearboxes);
- signal indicating the speed of the vehicle;
- signal indicating the engaged gear, in case of a robotized gearbox, or engagement of a neutral gear for manual gears.

The system described above allows providing the following operating modes:

gear with torque supply from the internal combustion engine alone (accelerator pressed, brake released, clutch closed, non-zero speed): the intake valves of the internal combustion engine are controlled so as to optimise the combustion efficiency, according to the conventional use of the MULTIAIR system;

gear with torque supply from the electric engine alone (e-motoring) in which the internal combustion engine is driven by the electric engine or it is in deceleration phase for cut-off (accelerator released, brake released, clutch closed, non-zero speed): in such conditions the intake valves of the engine are controlled so as to minimise the pumping losses (FIGS. 5,6), so as to minimise the deceleration of the vehicle, while the fuel injection is temporarily inhibited to minimise fuel consumption;

freewheel operating mode, with an internal combustion engine off and the wheels of the vehicle not connected to the power propulsion system: during the freewheel operation, two situations may occur with the internal combustion engine in run-down mode:

speed of the internal combustion engine above the minimum-run threshold: in this situation the intake valves are controlled so as to temporarily minimise the pumping losses to increase the engine run-down time, to allow a possible freewheel output with fuel re-injection (thus avoiding a BAS or starter engine start, if a starter is also provided for besides the BAS, i.e. an electric start motor);

speed of the engine below the minimum-run threshold: in this situation the following strategies may be actuated:

the intake valves are controlled so as to temporarily minimise the pumping losses to increase the engine run-down time to prepare to restart the engine (in case of change-of-mind of the driver) by engaging the clutch ("clutch pulse", only in case of automatic gearbox) or through BAS ('BAS cranking') or through a starter (starter cranking') of the type capable of restarting the engine even at non-zero engine speed;

the intake valves are controlled so as to temporarily maximise the pumping losses to reduce the engine run-down time with the aim of allowing a possible engine restart through a conventional starter as

soon as possible, if it is not possible to perform a clutch restart given that the gearbox is manual, or through BAS;

phase for starting the internal combustion engine (accelerator released, brake released, clutch open, zero speed): the intake valves of the engine are controlled so as to minimise the pumping losses (FIGS. 5, 6) for minimising the time for starting the internal combustion engine, using the electric machine EM as a starter.

As clear from the description above, the invention is thus based on a use of a system for variable actuation of the intake valves in an internal combustion engine of a motor vehicle provided with mild-hybrid power propulsion system with the aim of allowing new and more efficient operating modes of the system.

In the system described above, preferably it is further provided for that the variable actuation of the intake valves of the internal combustion engine be controlled so as to reduce the pumping losses even in engine cut-off conditions in which the BAS unit is used as a regeneration unit ('regenerative braking'). Thus the losses due to the engine are maintained minimum and the power regenerated by the alternator may be increased. Thus, the point lies in the fact that the internal combustion engine in cut-off, always optimizes the management of the variable actuation system of the engine valves and the electric machine is only required to control the vehicle coast-down.

Obviously, without prejudice to the principle of the invention, the construction details and the embodiments may widely vary with respect to what has been described and illustrated purely by way of example, without departing from the scope of protection of the present invention.

The invention claimed is:

1. A method for controlling a motor vehicle of the type comprising:

an internal combustion engine having a drive shaft with an output end connected through a transmission to at least one pair of wheels of the motor vehicle and an upstream end connected to one or more auxiliary devices through a belt transmission,

a BAS unit comprising an electric machine connected to said upstream end of the drive shaft through said belt transmission and controlled to operate as an electrical power generator, as an electric motor for starting the internal combustion engine and as an auxiliary engine for the propulsion of the motor vehicle, additionally to the internal combustion engine,

the method comprising:

maintaining the internal combustion engine in a cut-off condition and using the drive shaft as a simple transmission shaft in an e-motoring operating condition of the vehicle, said BAS unit being used as the only propulsion engine of the motor vehicle in the e-motoring operating condition;

providing said internal combustion engine with a system for variable actuation of the intake valves;

in the e-motoring operating condition wherein the BAS unit is used as the only propulsion engine, controlling the system for variable actuation of the intake valves of the internal combustion engine to vary the opening time and/or the closing time and/or the lift of the intake valves, so as to reduce the losses due to a pumping effect which occur within the internal combustion engine when it is driven in rotation by said BAS unit in a cut-off condition;

accelerating a switching off of the engine when the e-motoring operating condition is activated to allow a driver to promptly restart the engine in case of a change-of-mind of the driver; and

the accelerating comprising delaying an opening of an intake valve of the intake valves to increase the pumping losses to slow the engine to facilitate engagement of the engine and the driveshaft.

2. Method according to claim 1, wherein in the aforementioned operating conditions in which the BAS unit is used as the only propulsion engine, the system for variable actuation of the intake valves of the internal combustion engine is controlled to close the intake valves in advance with respect to a conventional intake cycle.

3. Method according to claim 1, wherein the internal combustion engine is provided with a system for variable actuation of the engine valves comprising at least one camshaft connected to the drive shaft, wherein each intake valve is controlled by a respective tappet actuated by a respective cam of said camshaft, against the action of spring means associated to each intake valve which return the intake valve towards a closed position, and in which said tappet is connected to said intake valve through hydraulic actuation means, comprising a pressure hydraulic chamber which can be connected to an exhaust channel through an electronically controlled solenoid valve, so as to decouple the intake valve from the respective cam and cause the closure thereof due to said return spring means.

4. Method according to claim 1, wherein said system for variable actuation of the intake valves is controlled so as to differently actuate intake valves associated to different cylinders and so as to differently actuate the same intake valve over time as a function of the engine operating conditions and detected by an electronic control unit through a plurality of sensors.

5. Method according to claims 1, wherein said operating condition, in which the BAS unit is used as the only propulsion engine, is activated with the vehicle stationary, to perform a vehicle start.

6. Method according to claim 1, wherein said operating condition, wherein the BAS unit is used as the only propulsion engine, is activated with the motor vehicle moving, when the operating conditions of the vehicle, of the engine and of the electrical system allow it.

7. Method according to claim 1, further comprising a freewheel operating mode, with the internal combustion engine off and the wheels of the vehicle not connected to the propulsion system.

8. Method according to claim 7, wherein when it is activated the freewheel operating mode, with the internal combustion engine in a run-down mode, the following strategies are activated:

if the speed of the internal combustion engine is above a minimum-run threshold, the intake valves are controlled so as to temporarily minimise the pumping losses to increase the engine run-down time, to allow a possible freewheel output with fuel re-injection (thus avoiding a BAS or starter engine start, if a starter is also provided for besides the BAS, i.e. an electric start motor);

if the speed of the engine is below the minimum-run threshold one of the following strategies are actuated:

the intake valves are controlled so as to temporarily minimise the pumping losses to increase the engine run-down time, to prepare to restart the engine with the engine moving;

the intake valves are controlled so as to temporarily maximise the pumping losses to reduce the engine

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run-down time, with the aim of allowing a possible engine restart with the engine stationary as soon as possible.

9. Method according to claim 1, wherein said operating phase, in which the BAS unit is used as the only propulsion engine of the motor vehicle, is started on the basis of a signal selected from among:

- an accelerator pedal position signal,
- a brake pedal position signal,
- a clutch condition signal,
- a signal indicating the speed of the vehicle,
- a signal indicating the engaged gear, in case of a servo-assisted gearbox, or engagement of a neutral gear, in case of a manual actuation gearbox.

10. Method according to claim 1, wherein the system for variable actuation of the intake valves is controlled to reduce the pumping losses even in the phase in which said BAS unit is used as a starter, to start the internal combustion engine.

11. Method according to claim 1, wherein the acceleration of the switching off is obtained by temporarily increasing the pumping losses of the internal combustion engine, by controlling the system for variable actuation of the intake valves such to cause a delayed opening, or a total absence of opening, of the intake valves.

12. Method according to claim 1, wherein the system for variable actuation of the intake valves of the internal combustion engine is controlled so as to reduce the pumping losses even in engine cut-off conditions in which the BAS unit is used as a regeneration unit.

13. A method for controlling a motor vehicle of the type comprising:

- an internal combustion engine having a drive shaft with an output end connected through a transmission to at least one pair of wheels of the motor vehicle and an upstream end connected to one or more auxiliary devices through a belt transmission,

- a BAS unit comprising an electric machine connected to said upstream end of the drive shaft through said belt transmission and controlled to operate as an electrical power generator, as an electric motor for starting the internal combustion engine and as an auxiliary engine for the propulsion of the motor vehicle, additionally to the internal combustion engine,

the method comprising:

maintaining the internal combustion engine in a cut-off condition and using the drive shaft as a simple transmission shaft in an e-motoring operating condition of the vehicle, said BAS unit being used as the only propulsion engine of the motor vehicle in the e-motoring operating condition,

providing said internal combustion engine with a system for variable actuation of the intake valves, and

in the e-motoring operating condition wherein the BAS unit is used as the only propulsion engine, controlling the system for variable actuation of the intake valves of the internal combustion engine to vary the opening time and/or the closing time and/or the lift of the intake valves, so as to reduce the losses due to a pumping effect which occur within the internal combustion engine when it is driven in rotation by said BAS unit in a cut-off condition;

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switching to a freewheel operating mode, such that the internal combustion engine is off and the wheels of the vehicle are not connected to the propulsion system.

wherein when the freewheel operating mode is activated, with the internal combustion engine in a run-down mode, the following strategies are activated:

if the speed of the internal combustion engine is above a minimum-run threshold, the intake valves are controlled so as to temporarily minimize the pumping losses to increase the engine run-down time, to allow a possible freewheel output with fuel re-injection thus avoiding a BAS or starter engine start when a starter is also provided for besides the BAS;

if the speed of the engine is below the minimum-run threshold one of the following strategies are actuated: the intake valves are controlled so as to temporarily minimize the pumping losses to increase the engine run-down time, to prepare to restart the engine with the engine moving;

the intake valves are controlled so as to temporarily maximize the pumping losses to reduce the engine run-down time, with the aim of allowing a possible engine restart with the engine stationary as soon as possible.

14. A method for controlling a motor vehicle of the type comprising:

- an internal combustion engine having a drive shaft with an output end connected through a transmission to at least one pair of wheels of the motor vehicle and an upstream end connected to one or more auxiliary devices through a belt transmission,

- a BAS unit comprising an electric machine connected to said upstream end of the drive shaft through said belt transmission and controlled to operate as an electrical power generator, as an electric motor for starting the internal combustion engine and as an auxiliary engine for the propulsion of the motor vehicle, additionally to the internal combustion engine,

the method comprising:

maintaining the internal combustion engine in a cut-off condition and using the drive shaft as a simple transmission shaft in an e-motoring operating condition of the vehicle, said BAS unit being used as the only propulsion engine of the motor vehicle in the e-motoring operating condition; providing said internal combustion engine with a system for variable actuation of the intake valves; in the e-motoring operating condition wherein the BAS unit is used as the only propulsion engine, controlling the system for variable actuation of the intake valves of the internal combustion engine to vary the opening time and/or the closing time and/or the lift of the intake valves, so as to reduce the losses due to a pumping effect which occur within the internal combustion engine when it is driven in rotation by said BAS unit in a cut-off condition;

accelerating a switching off of the engine when the e-motoring operating condition is activated to allow a driver to promptly restart the engine in case of a change-of-mind of the driver; and

switching to a freewheel operating mode, such that the internal combustion engine is off and the wheels of the vehicle are not connected to the propulsion system.

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